DOCUMENT RESUME

ED 295 645 IR 013 355

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TITLE Operationalizing Cognitive Constructs in the Design of Computer-Based Instruction.
PUB DATE 15 Jan 88
NOTE 18p.; In: Proceedings of Selected Research Papers presented at the Annual Meeting of the Association for Educational Communications and Technology (New Orleans, LA, January 14-19, 1988). For the complete proceedings, see IR 013 331.
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Aptitude Treatment Interaction; Branching; *Cognitive Style; *Computer Assisted Instruction; Courseware; *Field Dependence Independence; Individualized Instruction; *Instructional Design; Mastery Learning; *Student Characteristics

ABSTRACT

This study of the application of cognitive style theory to the development of computer-based instruction explored two questions, i.e., whether computer-based courseware can be designed to address specific learner characteristics, and, if so, which characteristics. Several factors involved in the optimization of instruction are described: learner adaptation, mastery learning, structure of knowledge, and individual differences. These factors are then considered in relation to the development of cognitive style constructs. The components of field dependence/independence (FD/I) cognitive style are then identified and their use in instructional design is briefly described. A matrix is developed to detail the bipolar nature of the FD/I concept, and learner characteristics and corresponding instructional strategies are detailed for both the field dependent and field independent branches of the design matrix. The text is supplemented by 3 figures and 15 references. (EW)

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OPERATIONALIZING COGNITIVE CONSTRUCTS IN THE DESIGN OF COMPUTER-BASED INSTRUCTION

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January 15, 1988

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ABSTRACT

The application of theory to the design of computer-based instruction (CBI) has been problematic due to missing substantive linkages between that theory and CBI development. A match between student's cognitive characteristics and the learning transaction may enhance learner satisfaction, reduce time on task and maximize learning. One body of theory that promises a significant impact on CBI development is that of cognitive styles. Greater efficiencies in student learning may be obtained by matching the individual's cognitive style with instructional presentations designed to enhance that cognitive processing. An important question to address is how to design the courseware and which cognitive style theory to employ.

STATEMENT OF THE PROBLEM

The computer has been used for the delivery of educational courseware for the last twenty years, but comparisons between computer-based instruction and other forms of instruction have demonstrated essentially no difference in achievement between the delivery systems (Clark 1982). Why is there no difference given the potential for individualization within the learning transaction? Perhaps the answer lies in the design of the computer courseware itself and not in the technology. The problem to be investigated in this paper is; Can computer-based courseware be designed to address specific learner characteristics, and if so, on which learner characteristics should the designer focus and how can those characteristics be addressed in the courseware?

Foundations

Educators strive to develop instructional material and presentation methodologies that are more effective and efficient than those which have gone before. Two approaches that have resulted from these efforts are those of mastery learning and individualization of instruction. These two complementary approaches represent attempts to address the goals of optimization and transfer of learning. Operationalizing these approaches has been difficult due to the many uncontrollable variables and individual differences commonly found in the learning situation. We know, for example, that individualization can enhance learning but is difficult in large groups. One way to overcome this difficulty is to provide individual delivery programs tailored to each learner. In this way the instruction is delivered to each individual in a format that is more easily processed.

Another variable that is difficult to provide for in large groups is sufficient time on task. The time it takes any given learner to master information is both variable and individual. If we could provide for these and other variables across a range of individual differences, then perhaps learning time could be reduced and comprehension enhanced. Individual tutoring for all learners could provide for this level of interaction but is obviously impractical. The identification of salient individual differences and their application to instruction in a flexible format could provide this level of interaction for every learner.

One such flexible format, computer-based instruction (CBI) holds great promise for the optimization and transfer of learning. The computer has the dynamic potential to perform many pedagogical functions such as; present information, focus attention, engage the learner in discussion, lead the learner to the correct response, provide feedback, branch for remediation based on learner response, allow for individual differences, test for mastery, branch from pretest to information required, present moving graphics, show real time action, video etc.. Within each of these categories more potential is hidden, and the number of categories that could be addressed are limited only by the imagination.

Computer-Based Instruction

Computer-based instruction, unlike traditional instructional methodologies, offers greater control of many previously uncontrollable variables. For example, the computer offers control of the learning environment, almost limitless adaptation capabilities and a full range of audio and visual inputs and outputs. The learner characteristics remain the same in both traditional instruction and computer-based instruction, but the use of computers in education can allow greater control of both the learning environment and instructional presentation. Why then has the promise of CBI gone unfulfilled?

Kulik's meta-analysis (1980) found computer-based instruction to be a more effective learning tool than all other presentation methodologies. Clark (1982),however, refutes Kulik's findings. He explains that most of the differences in performance described by Kulik's analysis can be explained by relative differences in the amounts of planning and instructional design time devoted to the competing presentation methodologies in the studies analyzed. The findings that CBI by requires more time to design and develop comes as no surprise. And while we concede that the application of the systematic development of instruction has improved the quality of computer-based instruction, any presentation methodology may benefit from that same process. However, even when course materials are identical, the computer offers conditions and options to the learner that cannot be efficiently applied in any other presentation methodology.

The lack of difference in performance between traditional presentation methodologies and CBI described by Clark may be explained by the fact that critical learning theory is not being systematically applied to development of computer-based instruction This fact suggests that until such learning theory is more clearly articulated to the developers, CBI can only be an alternate presentation media; no better or worse than those compared to it. Therefore the potential optimization of learning through CBT will not be achieved. What factors are involved in the optimatization of instruction?

Optimizing Instruction

Optimal instruction is that set of learning activities which minimizes cognitive resistance to the material to be learned. In other words, optimal instruction for one learner is not optimal for different learners with different sets of learning characteristics, (i.e., different cognitive styles). Attempts to maximize learning have focused on learner adaption, mastery, knowledge structure, and individualization.

Learner Adaptation

Adapting the learner to the learning situation in order to maximize performance shows some promise (Snow, 1984). However, care must be taken in this attempt to teach learning strategies rather than changing the presentation , since the learner is not necessarily the best judge of instructional method. Clark, (1982) found,"evidence in ATI (aptitude by treatment interaction) studies that students tend to report enjoying the instructional method from which they learn least." Based upon this information we cannot depend on the student to make the choice of a presentation methodology that will maximize their learning and transfer. A better approach, perhaps, would be to modify the instructional presentation to match with the learners' dominant learning pattern. The application of research on cognitive style to the learning task via the computer offers great potential for the maximization of learning.

Snow (1984) found in his study of Aptitude by Treatment Interaction (ATI) that, "the treatment that is mathemagenic (i.e., gives birth to learning) for one kind of learner appears to be mathemathanic (i.e., gives death to learning) for another kind of learner, and vice versa." This principle makes it increasingly important that the mathemagenic approach be identified and pursued. Applications of expert systems to CBI make it increasingly possible to mold instructional presentations to learner characteristics. This study will attempt to relate some learner characteristics to specific learning principles, thereby laying the groundwork for more specific application of these principles.

Mastery Learning

Each individual is different from his fellow in many ways, and learning is not the least of these. Bloom (1968) proposes that when learners with normally distributed aptitudes are given uniform instruction in terms of quality and time,

their achievements will also be normally distributed, and there will be a high correlation between aptitude and achievement. However, if learners with normally distributed aptitudes are given instruction that is optimal in terms of quality and required learning time, the majority of learners could be expected to achieve mastery, and there would be little or no correlation between aptitude and achievement.

Bloom assumes that time is the critical factor in maximizing learning. Time on task, however, is just one of many factors that contribute to learning. Bloom also refers to "optimal instruction" which he defines as individualized instruction. What set of characteristics or traits should the instruction reflect?

Structure of Knowledge

Gardner (1983) and Sternberg (1985) point out that learning is based upon two components: the learner and the material to be learned. Posner (1978) suggests that the structure of knowledge itself affects the "storage, retrieval, and utilization of knowledge" and that "previous experience and existing knowledge affect perception, communication, learning and performance of tasks." Reif and Heller (1982) suggest that in the teaching of physics, "considerable attention be paid to the organization of the knowledge acquired by students; that students be taught to structure their knowledge in hierarchical form; and that such knowledge be accompanied by explicit application guidelines." These recommendations were based upon research in the teaching of physics,but have implications for other quantitative sciences, as well.

To accomplish this effectively, a serious re-examination and synthesis of the principles of human cognition as they apply to the design of instruction for this medium is required. To accomplish this we must establish the existence of differences among various cognitive styles in the processing of information.

Individual Differences

The most important variable to be considered in the learning transaction is the learner. He brings a unique package of concepts, precepts and experience to the learning situation. This uniqueness has been referred to by many researchers as individual differences. Individual differences are many and varied. Those differences which facilitate or impair learning are critical but often

ignored in the learning situation. Group instruction will often present the information in a manner thought to address the average learner. Intelligence according to Gardner is not as simple a concept as the number on an I.Q. test, he postulates different intelligences by conceptual areas. I.Q., of course, is but one individual difference. Cognitive style underlies the perception and interpretation of the learners environment. and perhaps contributes to intelligence. These interrelationships are unclear and require further research. We do know, however, that there exist a set of measurable cognitive controls and styles. One cognitive style that has been well established and researched will form the basis for this study.

Learning via traditional approaches suffers and sometimes benefits from continuity between classes, consistency of delivery, consistency of content, interaction between students, interaction between teacher and student, and class dynamics, to mention a few. Individualization of instruction has been introduced to address these problems, but class size and time available for instruction reduce its efficacy in the classroom. The typical approach to individualization has often been small group instruction and remediation.

Approaches that focus on the individualization concepts have been attempted in the print medium with varying success. Here the problems of student motivation and pacing impact with learning. An approach that is ideal for one student often fails with another. Attempts to remedy this problem have resulted in multi-media and multi-methodological approaches in which a student may be presented with as many instructional formats as it takes to achieve mastery. Transfer of learning in enhanced by this approach, but efficiency of learning is not.

Cognitive Style Constructs

Studies begun in the early nineteen hundreds applied these scientific principles to human behavior in order to identify differences in the way people respond to ranges of situational variables. Spearman (1927), Lewin, Lippitt, & White(1939) are examples of this movement. The outcome of these early studies began to show that individuals did in fact process or perceive there environments differentially. Early thought centered around the identification of traits, abilities and attitudes. In order to answer questions related to these traits, abilities and

attitudes, they soon branched into studies of why there was a difference in processing environmental information to the identification of some of those differences. The construct of cognitive style was hypothesized to identify these differences in perception of environmental stimuli. Rather than explaining those differences in perception, the concept of cognitive style describes those differences. However, no adequate integration of the many cognitive styles, cognitive controls and individual differences has been accomplished to date. This fact does not degrade the concept that research into the separate cognitive styles can build upon the past research in a particular cognitive style. There is however some commonality between certain of the concepts.

That individuals have a collection of innate traits and abilities that mediate interpretation of stimuli is well established. They also learn strategies, programs or transformation operations to translate objective stimuli into meaningful dimensions (Bieri, 1971). Cognitive styles are therefore defined in terms of "consistent patterns of organizing and processing information that mediate between environmental input and the organism's output" (Messick, 1976) and "organize behavior as well as input " (Zajonc, 1968).

Field Dependence/Independence Dimension

Messick (1970) has summarized work in cognitive styles into nine categories. Many conceptual differences between and among the categories exist. No attempt as yet has integrated the cognitive styles into an information processing model, so we are left with the separate concepts of cognitive styles that may be applied in learning presentations.

Thompson (1979) found that the cognitive style of field dependence/ field independence was directly related to learning achievement. It is also this concept that has been most extensively studied. This dimension of cognitive style, offers considerable evidence concerning the processing of information which is applicable to the computer-based instruction environment. The field dependence/independence concept is described by Witkin as being bipolar. "At one extreme of the performance range perception is strongly dominated by the prevailing field (field dependence)" and "at the other extreme, where the person experiences items as more or less separate from the surrounding field, the designation 'field independent' was used." (Witkin, Moore, & Goodenough,

1977). The dimension described by Witkin was first identified in the investigation of perception, and it was further defined as having educational application. "Extensive evidence, accumulated over the years, shows that the styles we first identified in perception manifest themselves with symbolic representations, as in thinking and problem solving." (Witkin, 1977,). When Witkin found that the perceptual tasks he identified as field dependent/independent were related to non-perceptual intellectual tasks, the underlying construct was broadened to a "global-articulated" dimension. The field-independent person prefers to approach the environment in analytical terms as opposed to a preference for experiencing events globally in an undifferentiated fashion. Witkin (1977) relates that:

"Studies of the role of cognitive style in student learning have used both the cognitive and social characteristics constituent in the articulated-global dimension to conceptualize relations between learning behavior and cognitive style. Of the four learning areas we consider, the first two have used the social characteristics as a bridge between the domains. These two areas are learning of social material and the effects of social reinforcement. The third and fourth learning areas used mainly cognitive characteristics as a bridge. These are the areas of mediating mechanisms in learning and cue salience."

Field Independence

The field independent person experiences in an articulated fashion and tends to perceive items as discrete from their background when the field is organized, and to impose structure on the field, and so to perceive it as organized He/she is generally facile on tasks requiring differentiation and analysis, whether in identifying the presence of logical errors or in understanding the point of a joke. This analytical penchant leads to a high degree of differentiation of the self from its context (Anderson, Ball, Murphy, 1975). Witkin (1977) found that, "field independent persons are more likely to use mediators, of their own design, in dealing with a learning task.

Field Dependence

Field dependent persons are more likely to rely on characteristics of the learning task itself "rather than create mediators and that has a tendency to favor a spectator over an hypothesis testing approach" (Witkin, et.al; 1977) In contrast, it may be said that, "experience is more global when it accords with the

overall character of the prevailing field as given, and involves less intervention of mediators such as analysis and structuring". (Witkin, 1977).

In summary, Witkin found that performance on perceptual tasks was related to performance on non-perceptual tasks. He broadened the concept to an "articulated global", the dimension on which people tend to structure their perceptual field. The components that delineate the concept of the "articulated global" dimension are the need for social reinforcement, the learning of social material, importance of cue salience, and mediation in problem solving,

It is proposed that a marriage between CBI design components and cognitive structures of the individual utilizing the material would maximize information transmittal and minimize the time element required for learning, thereby making instruction more efficient and effective. The question remaining, however, is that of how to operationalize those cognitive constructs in the FD/FI cognitive style.

Operationalizing Cognitive Components

In order to utilize the components of a particular cognitive style in the design of instruction, the significant components must be identified. Once identified, corresponding treatments must be devised.

Many FD/FI characteristics have been identified in the literature, but, only those characteristics identified by Witkin (1977) and Renninger (1983) as having educational implications were considered in the development of the lesson to be used in this study. Instructional strategies were then applied to these cognitive style learner characteristics. For example, the Field Dependent learner, according to Witkin (et. al. 1977), has the following characteristics/requirements;

- an interpersonal orientation,
- extrinsic motivation,
- reinforcement,
- social cues,
- help sequences,
- structure,
- goals,
- feedback, and
- salient relevant cues.

The concept of FD/FI is bi-polar, therefore, the opposite characteristics apply to the Field Independent learner. Instructional strategies were then matched with these learning characteristics to create the treatment lesson. The two treatments or branches are characterized by the inclusion or exclusion of these instructional strategies while keeping the content constant.

In order to guide the development of the two treatments a design matrix was developed. The following matrix groups the cognitive characteristics into categories according to their similarities and identifies those strategies believed by the author to address those cognitive characteristics. The lesson material for each branch was then constructed to reflect these instructional strategies.

(Figure 1)

COGNITIVE STYLE LEARNING

CHARACTERISTIC/INSTRUCTIONAL STRATEGY MATRIX

FIELD DEPENDENT			FIELD INDEPENDENT	
INSTRUCTIONAL STRATEGIES	LEARNER CHARACTERISTICS *Spectator Approach*		LEARNER CHARACTERISTICS *Hypothesis Testing Approach*	INSTRUCTIONAL STRATEGIES
PERSONALIZED FEEDBACK	INTERPERSONAL ORIENTATION	→	SELF RELIANT	NO PERSONALIZED FEEDBACK
	EXTRINSICALLY MOTIVATED	→	INTRINSICALLY MOTIVATED	
	REINFORCEMENT NECESSARY	→	REINFORCEMENT UNNECESSARY	
	SOCIAL CUES NECESSARY	→	SOCIAL CUES UNNECESSARY	
PROVIDE ONLINE HELP	HELP SEQUENCES UTILIZED	→	INDEPENDENT PROBLEM SOLVING APPROACH	HELP OPTION ONLY IN BEGINNING
LEARNING STRUCTURE PROVIDED	FUNCTIONS WITHIN CONCEPTUAL STRUCTURE PROVIDED	→	STRUCTURES CONCEPTUAL ENVIRONMENT FOR COGNITIVE PROCESSING	DISCOVERY APPROACH NO STRUCTURE PROVIDED
	RELIES ON CHARACTERISTICS OF LEARNING TASK ITSELF	→	CREATES OWN MEDIATORS FOR LEARNING TASK	
	CONTEXT ORIENTATION	→	CONTENT ORIENTATION	
OBJECTIVES STATED	GOALS NECESSARY	→	REDEFINES PROBLEM GOALS IN OWN TERMS	ONLY BROAD GOAL PROVIDED
ERROR RELATED FEEDBACK	FEEDBACK NECESSARY	→	FEEDBACK UNNECESSARY	RIGHT/WRONG FEEDBACK FIRST TWO TRIALS
TASK RELATED FEEDBACK	RELEVANT CUES MUST BE SALIENT	→	RELEVANT CUES NEED NOT BE SALIENT	THIRD FEEDBACK WILL CONTAIN CORRECTIVE FEEDBACK

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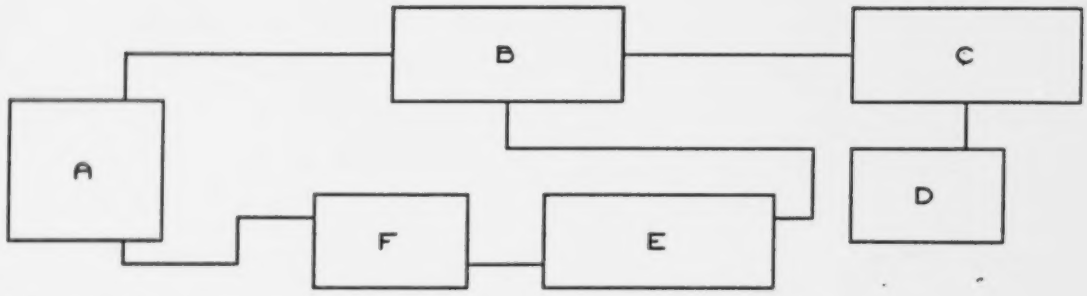
Example

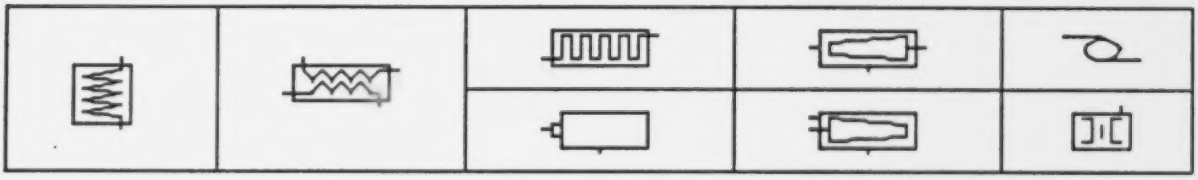
The design of any courseware is a creative endeavor.and design approaches differ dramatically. To illustrate one approach in an attempt to operationalize the cognitive constructs of field dependence and field independence, the author has chosen a lesson in Thermodynamics Two branches were created, one for each of the cognitive styles represented in the design matrix. The field dependent branch most closely resembles what can be considered the traditional, spectator approach to CBI design. Objectives are stated early in the lesson, content presented in graphic and text and finally questions presented.with personalized, error related feedback. Help is always available. The field independent path represents an hypothesis testing approach to CBI design. Features in this path include broad goals instead of specific objectives, right/wrong feedback without further cues, and a discovery approach to interacting with the materials. Help is available only at the beginning of this branch.

fr30

The BWR as a "System"

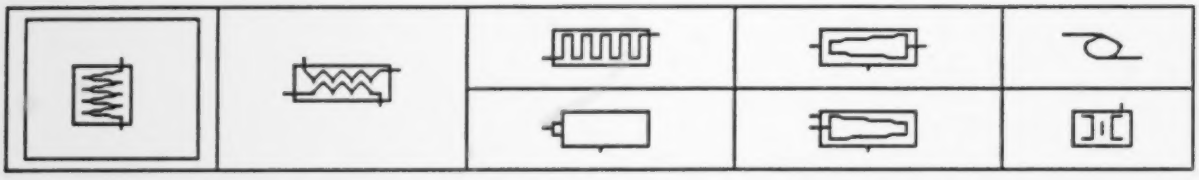


Using the arrow keys (←,→,↑,↓) or touch, move the cursor (the small "+" symbol) to the area you wish to select, then press NEXT.



Field Dependent Branch

Use touch or the arrow keys (←,→,↑,↓) to select a symbol, then press NEXT. Press SHIFT-NEXT to judge your drawing.



Press HELP for a description of what each symbol represents.

Field Independent Branch

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